PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY
(Chapter II of the Patent Cooperation Treaty)

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference
M33315WO

FOR FURTHER ACTION
See Form PCT/PEA416

International application No.
PCT/US2015/054102

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08.10.2014

International Patent Classification (IPC) or national classification and IPC
INV. G06K9/00

Applicant
MICROSOFT CORPORATION

1. This report is the international preliminary examination report, established by this International Preliminary Examining Authority under Article 35 and transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 11 sheets, including this cover sheet.

3. This report is also accompanied by ANNEXES, comprising:
   a. ☑ (sent to the applicant and to the International Bureau) a total of 5 sheets, as follows:
      ☑ sheets of the description, claims and/or drawings which have been amended and/or sheets containing rectifications authorized by this Authority, unless those sheets were superseded or cancelled, and any accompanying letters (see Rules 46.5, 66.8, 70.16, 91.2, and Section 607 of the Administrative Instructions).
      ☐ sheets containing rectifications, where the decision was made by this Authority not to take them into account because they were not authorized by or notified to this Authority at the time when this Authority began to draw up this report, and any accompanying letters (Rules 66.4bis, 70.2(e), 70.16 and 91.2).
      ☐ superseded sheets and any accompanying letters, where this Authority either considers that the superseding sheets contain an amendment that goes beyond the disclosure in the international application as filed, or the superseding sheets were not accompanied by a letter indicating the basis for the amendments in the application as filed, as indicated in item 4 of Box No. I and the Supplemental Box (see Rule 70.16(b)).
   b. ☑ (sent to the International Bureau only) a total of [indicate type and number of electronic carrier(s)] containing a sequence listing, in the form of an Annex CST.25 text file, as indicated in the Supplemental Box Relating to Sequence Listing (see paragraph 3ter of Annex C of the Administrative Instructions).

4. This report contains indications relating to the following items:
   ☑ Box No. I Basis of the report
   ☑ Box No. II Priority
   ☑ Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   ☑ Box No. IV Lack of unity of invention
   ☑ Box No. V Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
   ☑ Box No. VI Certain documents cited
   ☑ Box No. VII Certain defects in the international application
   ☑ Box No. VIII Certain observations on the international application

Date of submission of the demand
20.04.2016

Date of completion of this report
05.01.2017

Name and mailing address of the international preliminary examining authority:
European Patent Office P.B. 5818 Patentlaan 2
NL-2280 HV Rijswijk - Pays Bas
Tel. +31 70 340 - 2040
Fax: +31 70 340 - 3016

Authorized officer
Hermes, Lothar
Telephone No. +31 70 340-2011

Form PCT/PEA/409 (cover sheet) (January 2015)
Box No. 1  Basis of the report

1. With regard to the language, this report is based on
   ☑ the international application in the language in which it was filed
   ☐ a translation of the international application into , which is the language
     of a translation furnished for the purposes of:
     ☐ international search (under Rules 12.3(a) and 23.1(b))
     ☐ publication of the international application (under Rule 12.4(a))
     ☐ international preliminary examination (under Rules 55.2(a) and/or 55.3(a) and (b))

2. With regard to the elements* of the international application, this report is based on (replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report):

Description, Pages
1-14 as originally filed

Claims, Numbers
1-12 filed with telefax on 31-10-2016

Drawings, Sheets
1/7-7/7 as originally filed

☐ a sequence listing - see Supplemental Box Relating to Sequence Listing.

3. ☑ The amendments have resulted in the cancellation of:
   ☐ the description, pages
   ☑ the claims, Nos. 13-15
   ☐ the drawings, sheets/figs
   ☐ the sequence listing (specify):

4. ☑ This report has been established as if (some of) the amendments annexed to this report and listed below had not been made, since either they are considered to go beyond the disclosure as filed, or they were not accompanied by a letter indicating the basis for the amendments in the application as filed, as indicated in the Supplemental Box (Rules 70.2(c) and (c-bis)):
   ☐ the description, pages
   ☑ the claims, Nos. 7,10
   ☐ the drawings, sheets/figs
   ☐ the sequence listing (specify):

5. ☐ This report has been established:
   ☐ taking into account the rectification of an obvious mistake authorized by or notified to this Authority under Rule 91 (Rules 66.1(d-bis) and 70.2(e)).
   ☐ without taking into account the rectification of an obvious mistake authorized by or notified to this Authority under Rule 91(Rules 66.4bis and 70.2(e)).
6. ☑ With regard to top-up searches (Rules 66.1ter and 70.2(f)):
   ☑ A top-up search was carried out by this Authority on 23.08.2016 (all discovered documents are listed in the Supplemental Box Relating to Top-up Search).
   ☑ Additional relevant documents have been discovered during the top-up search.
   ☐ No top-up search was carried out by this Authority because it would serve no useful purpose.

7. ☐ Supplementary international search report(s) from Authority(ies) has/have been received and taken into account in establishing this report (Rule 45bis.8(b) and (c)).

* If item 4 applies, some or all of those sheets may be marked "superseded".

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**Box No. V**

Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

   | Novelty (N) | Yes: Claims | 1-6, 8, 9, 11, 12 |
   | Inventive step (IS) | Yes: Claims | 1-6, 8, 9, 11, 12 |
   | Industrial applicability (IA) | Yes: Claims | 1-6, 8, 9, 11, 12 |

2. Citations and explanations (Rule 70.7):

   [see separate sheet]

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**Box No. VIII**

Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:

[see separate sheet]
Re Item I

Basis of the report

1 The amendment filed with the letter dated 31-10-2016 introduces subject-matter which extends beyond the content of the application as filed, contrary to Art. 34(2)(b) PCT. The reasons are as follows.

1.1 The applicant has amended claim 5 to define steps of, inter alia,

"obtaining a series of three or more images, the images acquired by the camera at different levels of illumination of the illumination system" and

"analyzing the obtained images and selecting first and second images from the series of obtained images which exhibit [...] strong but unsaturated bright pupil reflections" (claim 5, lines 4-7).

1.2 Claim 7 depends on claim 5. In addition to what is defined by claim 5, claim 10 defines that

"the reflection by the eye includes a reflection [...] causing a pupil of the eye to appear dark relative to the iris in the first image" (claim 7, ll. 1-3).

1.3 Claim 10 also depends on claim 5. Claim 10 additionally defines that

"obtaining the second image of the eye includes multiplying a brightness of each unsaturated pixel of the first image by a multiplication factor to obtain a corresponding pixel of the second image" (claim 10, lines 1-3).

1.4 The above-mentioned steps of claim 5 have been adopted from par. 40 of the description (p. 9, ll. 22-28: " [...] gaze-detection engine 46 may be configured to analyze a series of three or more images acquired at different illumination levels, and then select appropriate first and second images [...] which exhibit [...] strong but unsaturated [...] bright-pupil reflections").

1.5 Unlike what is defined by claim 7, however, paragraph 40 does not state that a pupil should appear dark relative to the iris. On the contrary, a pupil, which appears dark relative to the iris, is actually the exact opposite of the bright-pupil effect taught in paragraph 40 (p. 9, ll. 22-28: " [...] gaze-detection engine 46 may be configured to [...] select appropriate first and second images [...] which exhibit [...] bright-pupil reflections"). Thus, the combination of features defined by claim 7 is not disclosed in the application as originally filed.

1.6 Paragraph 40 does not disclose the additional feature of claim 10, either. Instead, it states that the above-mentioned steps of claim 5 address the problem that "the eyes of different individuals may require different levels of
on-axis illumination to yield a bright-pupil response" (p. 9, ll. 20-22): "In this manner, the first and second levels of illumination, in method 74, may be selected based on ability to evoke and distinguish a bright pupil effect in the imaged eye, such levels differing for eyes of different users" (p. 9, ll. 28-30). If the pixels of the second image are obtained by simply multiplying unsaturated pixels of the first image by a multiplication factor (current claim 10, as quoted above), then the two images will not differ with regard to the presence or absence of a bright pupil response. Instead, the second image, albeit generally appearing brighter, will only exhibit the desired bright-pupil response if the first image also exhibits a bright-pupil response. Thus, the feature defined by claim 10 is inconsistent with the context, in which the above-mentioned steps of claim 5 are disclosed in the description. Consequently, the combination of features defined by claim 10 also extends beyond the content of the application as originally filed.

1.7 In conclusion, the application as originally filed does not disclose the subject-matter of claims 7 and 10.

Re Item V

Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

2 Reference is made to the following documents:


Document D1 is considered as being the closest prior art.

3.1 Document D1 discloses a system (Sect. II.C) comprising:

an illumination system (Sect. II. C, II. 26-27: "The center LED, in coaxial with the camera, and the off-center LED, uncoaxial with the camera") configured to illuminate an eye (Sect. II.C: I. 24: ":[... ] glued toward the camera’s subject");

a camera (Sect. II.C, II. 1-3: "A standard interlaced scanning CCD camera [...] having near-infrared sensitivity was used") configured to acquire one or more images of the eye (Sect. II.C: "Images of his right eye were obtained"); and

operatively coupled to the camera and the illumination system, a processor and associated computer memory (Sect. II.C, II. 61-65: "The obtained images were processed later by a personal computer (NEC PC9801DA2) through the imaging board"), the computer memory holding instructions executable by the processor to

compare brightness of corresponding pixels (Fig. 1(c): "Difference image"; Fig 2: "Differentiation (Odd - Even)") of a selected first image (Fig. 1 (a): "Odd field image"; Fig. 2: "Odd") and a selected second image (Fig. 1(b): "Even field Image"; Fig. 2: "Even") to distinguish a reflection of the illumination by the eye (Figs. 1(d), 1(e), 2(a): "Glint"; Fig. 2: "pupil remaining process") from a reflection of the illumination by eyewear (Fig. 2(g): "Reflected light on glasses"; Fig. 2: "glass reflection light elimination process"), and

furnish input to the computer system based on the reflection of the illumination by the eye and independent of the reflection of the illumination by the eyewear (Sect. V: "In this paper, [...] for users wearing eye glasses, a method was proposed to precisely detect not only the pupil but also the glint, which is another feature area to determine the eye-gaze position").

3.2 Document D1 also discloses a process of calibrating the level of illumination, the process comprising

obtaining a series of images, the images acquired by the camera at different levels of illumination of the illumination system, analysing the obtained images, and selecting the second image from the series of obtained images
(Sect. II.C, ll. 39-42: "[...] the off-center LED current when lit up was controlled and the brightness in the surroundings of the pupil in the even field images was adjusted to that of the odd field images on a black and white video monitor for camera-image feedback"); and

feeding back a second level of illumination used for the selected second image to be used for a subsequent series of two images to be obtained (Sect. II.C, ll. 58-59: "Either with or without eye glasses, consecutive odd and even field images were taken using the imaging board"; Fig. 4: "ODD IMAGE", "EVEN IMAGE").

3.3 The subject-matter of claim 1 differs from the known system in that

a. the series of images comprises three or more images;

b. the selection process additionally selects the first image,

c. the selected images exhibit saturated eyeglass reflections and strong but unsaturated bright pupil reflections,

d. the feedback additionally includes feeding back a first level of illumination used for the selected first image,

e. the step of comparing brightnesses of corresponding pixels comprises associating the corresponding pixels of the first and second images with the reflection of the illumination by the eye if the brightness of such pixels differs by more than a threshold amount and associating the corresponding pixels of the first and second images with the reflection of the illumination by the eyewear if the brightness of such pixels differs by less than a threshold amount, and

f. all processes are implemented as instructions stored in the computer memory and executable by the processor.

3.4 The subject-matter of claim 1 is, therefore, new (Article 33(2) PCT).

4 The problem to be solved by features (a) to (e) is considered as how to provide an alternative method of distinguishing a reflection by the eye from a reflection by eyewear. Feature (f) addresses the separate problem of how to increase the level of automation.
4.1 The claimed solution to the first problem evokes a bright pupil response in both the first and the second image, subject to the additional constraint that the eyeglass reflections must be saturated in both images (cf. features (a) to (d) in point 3.3 above). Subsequently, a thresholding operation operation is applied to the difference image (cf. feature (e) in point 3.3 above).

4.2 In contrast, document D1 teaches to solve the first problem by
   - evoking a bright pupil response in the first image (Fig. 1(a) and (d)),
   - evoking a dark pupil response in the second image (Fig. 1(b) and (e)),
   - calculating the difference image (Fig. 1(c) and (f) and Fig. 2(a) and(g)),
   - and, subsequently,
   - subjecting the difference image to thresholding, binarisation, and morphological operations (Fig. 2(b) to (f) and (h) to (l)).

4.3 This alternative solution to the first problem is different from the claimed solution (i.e. the solution defined by features (a) to (e)). Thus, document D1 does not render the claimed solution obvious.

4.4 Document D2 teaches to solve the first problem by counting white pixels in an image taken at low exposure time and subjecting the determined number to a thresholding operation (p. 2114, par. 2). This teaching does not render the claimed solution obvious, either.

4.5 Document D3, published by the same author as document D1, describes the same illumination and imaging hardware as document D1 (cf. D3, first paragraph in subsection "Methods" of Sect. 3). Unlike document D1, document D3 teaches to calibrate the illumination levels of both the on-center and the off-center LEDs (D3, subsection "Methods" of Sect. 3, first paragraph: "[...] The center LED current was set at 25-150 mA (9 levels), and then the off-center LED current was controlled and the brightness in the surroundings of the eye in the even field images was adjusted to that of the odd field images"). The calibration process according to D3 involves series of at least nine images (D3, Fig. 9). Its results are used as feedback for selecting appropriate illumination levels for the on-center LED (Sect. 4, subsection "Method for pupil brightness stabilization"). Said on-center LED provides the illumination for the first image (D3, Sect. 2, last paragraph: "In the pupil detection technique using two light sources and the image difference method, one light source set in coaxial with the camera is switched on during the odd fields of the video signal [...]”). Thus, document D3 discloses features (a), (b),
and (d). However, document D3 does not feature (c) and (e), because in consistency with document D1 it teaches to evoke a dark pupil response for the second image (D3, Figs. 1(b) and (e)). Consequently, document D3 does not render the claimed solution obvious, either.

4.6 Since there is no evidence that the claimed solution to the first problem is obvious in view of the prior art, the subject-matter of claim 1 of the present application is considered as involving an inventive step (Art. 33(3) PCT).

4.7 Claim 5 mirrors the features of claim 1 in terms of steps of a corresponding method. Since the subject-matter of claim 1 involves an inventive step, so does the one of claim 5.

4.8 Claims 2-4 and 6-12 are dependent on claims 1 and 5, respectively. As such they also meet the requirements of the PCT with respect to novelty and inventive step.

Re Item VIII

Certain observations on the international application

5 Contrary to what is stipulated in Art. 5 PCT, the description does not disclose the presently claimed invention in a manner sufficiently clear and complete for it to be carried out by a person skilled in the art.

5.1 The applicant has amended claim 1 to define "A system comprising [...] computer memory holding instructions executable [...] to obtain a series of three or more images [...] at different levels of illumination" and to "analyze the obtained images and select first and second images from the series of obtained images which exhibit saturated eyeglass reflections and strong but unsaturated bright pupil reflections" (claim 1, lines 1-11).

5.2 In analogy, the applicant has also amended claim 5 to define, "Enacted in a computer system [...], a method [...] comprising [...] obtaining a series of three or more images [...] at different levels of illumination" and "analyzing the obtained images and selecting first and second images from the series of obtained images which exhibit saturated eyeglass reflections and strong but unsaturated bright pupil reflections" (claim 5, lines 1-8).

5.3 The wording of claims 1 and 5, as quoted above, is interpreted in the sense that the system should be configured to perform the image analysis and the selection of the first and second images in an automated fashion.
5.4 The applicant has referred to step 82 in Fig. 7 and to the description in paragraphs 40-42 as the basis for the amendment.

5.5 Indeed par. 40 comprises the following statement:

"[…] gaze-detection engine 46 may be configured to analyze a series of three or more images acquired at different illumination levels, and then select appropriate first and second images to refine the first and second levels of illumination, as illustrated at 82 in FIG. 7. The images selected may be those […] which exhibit saturated eyeglass reflections, and strong but unsaturated (e.g., > 30% saturated intensity, >50% as examples) bright pupil reflections" (p.9, ll. 22-28).

5.6 However, the above-quoted statement does not give any technical teaching about how to actually implement said step 82 of analyzing the three or more images for subsequently selecting the first and second images. In particular, the statement does not explain how to determine whether an image satisfies the criterion of exhibiting saturated eyeglass reflections and strong but unsaturated bright pupil reflections.

5.7 As a prerequisite for applying this criterion in an automated fashion, the system would need to execute instructions for initially distinguishing eyeglass reflections from bright pupil reflections. Only after having successfully executed these instructions, the system would be able to confirm that the first kind of reflections are saturated and that the latter kind of reflections are strong but unsaturated.

5.8 The present application does not disclose such instructions. As shown in Fig. 7, the step of distinguishing eyeglass reflections from bright pupil reflections (i.e. step 84) is performed subsequently to step 82. Thus, the result of step 84 is not known to the system at the time when the system is supposed to perform step 82. The sequence of steps 82 and 84 cannot be inverted, because step 84 relies on the output of step 82 (i.e., appropriately selected first and second images) as one of its input parameters (see, e.g., the penultimate paragraphs of claims 1 and 5, respectively). Thus being ignorant of the result of step 84, step 82 will not succeed in applying the above-mentioned criterion for selecting appropriate first and second images.

5.9 The above analysis shows that the skilled person would be unable to apply the mentioned criterion in an automated fashion. Yet claims 1 and 5 require the image analysis and the selection of first and second images according to
the above-mentioned criterion to be implemented as computer instructions to be executed by a processor. Consequently, the subject-matter of claims 1 and 5 does meet the requirements of Art. 5 PCT.

5.10 The same objection applies to claims 2-4 and 6-12, which are dependent on claims 1 and 5, respectively.

6 The above mentioned issue under Art. 5 PCT notwithstanding, claims 1 and 5 do not meet the requirements of Art. 6 PCT in that they are not clear. The reasons are as follows.

6.1 Claim 1 is prone to be interpreted in the sense that the steps of

"associating the corresponding pixels of the first and second images with the reflection of the illumination by the eye if the brightness of such pixels differs by more than a threshold amount and associating the corresponding pixels of the first and second images with the reflection of the illumination by the eyewear if the brightness of such pixels differs by less than a threshold amount" (claim 1, ll. 11-16) and

"compare brightness of corresponding pixels of the selected first and second images to distinguish a reflection of the illumination by the eye from a reflection of the illumination by eyewear" (claim 1, ll. 20-22)

are two separate steps, although the former step actually implements the latter (cf. par. 44 of the description). Claim 1 is, therefore, unclear.

6.2 The same objection applies, mutatis mutandis, to claim 5.

6.3 Claims 1 and 5 are also unclear because the vague and unclear phrase "strong but unsaturated [...] reflections" (claim 1, ll. 10-11; claim 5, ll. 7-8) leaves the reader in doubt as to the meaning of the technical feature to which it refers.

6.4 Furthermore, the clarity of claim 5 is affected by some editorial errors ("[...] used for the selecting first image and [...] for the selecting second image" at lines 14-15 of claim 5 should probably read "[...] used for selecting the first image and [...] for selecting the second image").
International Application PCT/US2015/054102
GAZE TRACKING THROUGH EYEWEAR
Microsoft Technology Licensing, LLC et al.

In response to the Written Opinion of the International Preliminary Examining Authority dated September 1, 2016:

Applicant herewith submits replacement claims 1 to 12 that shall replace the present claims and shall be taken as the basis for further examination.
Replacement claim 1 is based on former claims 1 and 12 and the description at page 9, lines 26 to 28. Thus replacement claim 1 should be now in the form as proposed by the International Preliminary Examining Authority. If there should be a misunderstanding, it is respectfully requested to contact the undersigned by telephone for clarifying this point and enabling the applicant to appropriately amend the claims or to give a hint how an allowable claim could read.

Replacement claims 2 to 4 correspond to former claims 2 to 4.

Replacement claims 5 is based on former claims 5 and 12 and adapted to replacement claim 1.

Replacement claims 6 to 11 correspond to former claims 6 to 11.

Finally, replacement claim 12 is based on former claim 15.

Dr. Uwe Manasse
Patent Attorney

Enclosure:
Replacement claims 1 to 12
(marked-up and clean version)
1. A system comprising:

an illumination system configured to illuminate an eye;

a camera configured to acquire one or more images of the eye; and

operatively coupled to the camera and the illumination system, a processor and associated computer memory, the computer memory holding instructions executable by the processor to

obtain a series of three or more images, the images acquired by the camera at different levels of illumination of the illumination system;

analyze the obtained images and select first and second images from the series of obtained images which exhibit saturated eyeglass reflections and strong but unsaturated bright pupil reflections, associating the corresponding pixels of the first and second images with the reflection of the illumination by the eye if the brightness of such pixels differs by more than a threshold amount and associating the corresponding pixels of the first and second images with the reflection of the illumination by the eyewear if the brightness of such pixels differs by less than a threshold amount;

feed back a first level of illumination used for the selected first image and a second level of illumination used for the selected second image to be used for a subsequent series of two images to be obtained;
compare brightness of corresponding pixels of the selected first and second images to distinguish a reflection of the illumination by the eye from a reflection of the illumination by eyewear; and

furnish input to the computer system based on the reflection of the illumination by the eye and independent of the reflection of the illumination by the eyewear.

2. The system of claim 1, further comprising instructions executable to capture one or more of the first image of the eye and the second image of the eye in multiple exposures.

3. The system of claim 1, wherein the instructions are executable to acquire the first image of the eye and the second image of the eye successively before reading the first image of the eye and the second image of the eye from the camera.

4. The system of claim 1, wherein the lamp is configured to transition from providing the first level of illumination to providing the second level of illumination in thirty milliseconds or less.

5. Enacted in a computer system operatively coupled to a vision system, a method to furnish input representing gaze direction, the method comprising:

from a camera of the vision system,

obtaining a series of three or more images, the images acquired by the camera at different levels of illumination of the illumination system;

analyzing the obtained images and selecting first and second images from the series of obtained images which exhibit saturated eyeglass reflections and strong but unsaturated bright pupil reflections, associating the corresponding pixels of the first and second images with the reflection of the illumination by the eye if the brightness of such pixels differs by more than a threshold amount and associating the corresponding pixels of the first and second images with the reflection of the illumination by the eyewear if the brightness of such pixels differs by less than a threshold amount;
feeding back a first level of illumination used for the selecting first image and a second level of illumination used for the selecting second image to be used for a subsequent series of two images to be obtained; comparing brightness of corresponding pixels of the selected first and second images to distinguish a reflection of the illumination by the eye from a reflection of the illumination by eyewear; and furnishing the input based on the reflection of the illumination by the eye.

6. The method of claim 5, wherein the reflection of the illumination by the eye includes a reflection from a retina of the eye, the reflection passing back through a pupil of the eye and causing the pupil to appear bright relative to a surrounding iris in the first image.

7. The method of claim 5, wherein the reflection by the eye includes a reflection by an iris of the eye, causing a pupil of the eye to appear dark relative to the iris in the first image.

8. The method of claim 5, further comprising computing the input based on a location, in the first image, of the reflection of the illumination by the eye, while excluding those pixels associated with the reflection of the illumination by the eyewear.

9. The method of claim 8, further comprising correcting the input based on a kinematic model to account for movement of the eye between obtaining the first and second images.

10. The method of claim 5, wherein obtaining the second image of the eye includes multiplying a brightness of each unsaturated pixel of the first image by a multiplication factor to obtain a corresponding pixel of the second image.

11. The method of claim 5, wherein the input furnished includes an azimuth angle and an elevation angle defining a direction of sight through the eye.

12. The method of claim 5, wherein the first level of illumination is selected based on ambient light conditions.